PERFORMANCE AND STABILITY EVALUATION OF SOME GRAIN SORGHUM GENOTYPES

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Abstract

Sixteen grain sorghum genotypes *(Sorghum bicolor* (L.) Moench) of diverse origin were evaluated during 2008 and 2009 growing seasons under two rates of nitrogen fertilizer (60 and 100 kg N/fad) at two locations, i.e. Shandaweel and Sids Agric. Res. Stations (eight environments). The results showed highly significant differences among genotypes and environments for all the studied traits. Moreover, the genotype × environment interaction was also highly significant for all the studied traits. The results showed different response of genotypes from year to year and from location to another for all studied traits. Means of plant height, 1000 grain weight, and grain yield per plant of the 16 genotypes decreased clearly with decreasing nitrogen fertilizer from 100 Kg /fad to 60 Kg /fad at Shandaweel and Sids in the two seasons.

The joint regression analysis of variance for the studied traits showed that the variances due to genotypes, environments and genotypes × environments interaction were highly significant for all studied traits, indicating that genotype varied considerably across different environments. Env. + (Genotypes × environments) interaction was partitioned to environment (linear), genotype × environment interaction (linear) (sum of squares due to regression, bi) and pooled deviation mean squares, S2d. The G × E interactions were a linear function, which were significant for all the studied traits, except for days to 50% flowering. The stability parameters (bi and S2d) for grain yield per plant, showed that the genotypes varied in their bi values as well as S2d. It could be noticed that the regression coefficient (bi) for genotypes (RTX-436), (ICSV-273) and (ICSR-89037) were insignificant from unity and the deviation from regression (S2d) were insignificant from zero, indicating that these genotypes could be considered stable for grain yield per plant. Two genotypes had grain yield higher than the grand mean (ICSV-273 and ICSR-89037).

Key words: Sorghum, Stability, nitrogen fertilizer, Regression coefficient

INTRODUCTION

Breeding for the harsh environmental conditions has become some of the essential objectives to avoid the expected irrigation water shortage, nitrogen fertilizer poverty and climate changes. Therefore, the estimates of the genotypes stability became necessary and important policy of the Field Crops Research Institute (FCRI).

Stability of yield, defined as the ability of genotype to avoid substantial fluctuations in yield across a range of environments. Mechanisms of yield stability fall into four general categories; genetic heterogeneity, yield component compensation, stress tolerance, and capacity to recover rapidly from stress Heinirich *et al.* (1983).

Desai, *et al.* (1983) reported a significant G x E interactions in sorghum hybrids, and high yielding ability of hybrids, which was primarily due to better management. Saeed, *et al.* (1984) revealed that genotypes showed larger interaction with locations within a year than with years irrespective of maturity. They suggested that testing genotypes at more locations should be done rather than testing genotypes in more years. Moreover, they stated that increasing number of replications per test more than two, environments more than eight in a year, and years of testing more than two, was not effective in increasing efficiency in genotypes evaluation, especially for early and medium maturing genotypes. Eweis (1998) carried out a stability study across 14 different production environments at Middle and Upper Egypt and stated that genotype × environment interactions were always highly significant that suggested estimating yield stability in selection programs. Ali (2000) found that mean squares due to crosses × environments (linear) interaction were highly significant for panicle weight and grain yield. In this regard, Mourad *et al* (2000) reported that panicle weight, grain yield per panicle, 1000 grain weight, green yield, total biomass and grain yield significantly increased by increasing nitrogen fertilizer rates from 80 to 100 kg/fad. Mostafa (2001) reported that genotypes and genotypes × year's interactions for all studied traits were significant, while those due to years and genotypes x years interaction for 1000- kernel weight, were not significant. Lee, *et al.* (2003) suggested that grain yield stability could be improved through recurrent selection via selecting merely for mean performance across multiple environments. Ali (2006) found that, the joint regression analysis of variance showed significant and highly significant variances due to genotypes, environments and the genotype × environment interaction for most the studied traits. The stability parameters indicated that six genotypes were more stable for number of days to flowering, five genotypes for plant height, two for grain yield/plant, and 7 genotypes for 1000 grain weight. Mahmoud *et al* (2007) reported that, highly significant genotypes x environment interactions were found for all the studied traits. A large portion of this interaction was accounted for the linear regression on the environmental means. But the nonlinear component was noticeably small portion. Stability parameters across all environments indicated that, all genotypes exhibited significant linear response to environmental conditions. Mahdy *et al* (2011) revealed that, the interaction effects of genotypes with locations and planting dates were highly significant for all studied traits, whereas genotype x year interaction effect was highly significant for days to blooming, plant height and grain yield. Genotype x year x planting date interaction effect was highly significant for plant height, 1000-grain weight and grain yield. However, genotype x year x location x planting date interaction effect was highly significant only for plant height and grain yield. Four genotypes (three crosses; (A-73 x R-272), (A-604 x R-92010) and (A-613 x R-210) and one parent (R-273)) were the best stable genotypes. These genotypes gave higher yields compared to the average overall genotypes (hybrids and parents, respectively). These genotypes were considered as promising cultivars and may be suitable for growing in a wide range of environments.

The main objective of the present investigation was to study the performance and stability parameters of yield and its components in grain sorghum genotypes tested under eight environments (the combinations of 2 years × 2 locations × 2 levels of nitrogen fertilizers).

MATERIALS AND METHODS

Sixteen grain sorghum genotypes (*Sorghum bicolor* (L.) Moench) of diverse origin (Table 1) and one check variety (Dorado) were evaluated under eight environments. These environments were resulted from combinations of two rates of nitrogen fertilizer (60 and 100 kg N/fad), at two locations, *i.e.* Shandaweel and Sids Agric. Res. Stations and two growing seasons 2008 and 2009. The experimental layout was a randomized complete blocks design with three replications for each experiment in this investigation. Each genotype was sown in one row 4.0 m long and 60 cm apart. Planting were done in hills spaced 15 cm apart within row and seedling were thinned to two plants per hill. Planting dates were June 22nd and 23rd and June 21st and 22nd at Shandaweel and Sids in 2008 and 2009 growing seasons, respectively. The recommended cultural practices of sorghum production were implemented except the amount of supplemented nitrogen. Data were recorded on days to 50% flowering, Plant height (cm), 1000 grain weight (g), and grain yield/plant (g). The grain moisture was adjusted to 14% moisture.

Table 1. Origin of the sixteen grain sorghum genotypes.

No.	genotype	Origin	No.	genotype	Origin
1	RTX - 430	USA	9	ICSR - 89037	INDIA
2	RTX - 433	USA	10	R - 542	Zimbabwe
3	RTX - 436	USA	11	R - 625	Zimbabwe
4	RTX - 2817	USA	12	R - 924	Zimbabwe
5	RTX - 2862	USA	13	ZSV - 14	Zimbabwe
6	ICSR - 273	India	14	MR - 812	Zambia
7	ICSR - 138	India	15	GD - 47809	USA
8	ICSR - 89025	India	16	GD - 47815	USA

Stress susceptibility index (SSI)

Stress susceptibility index (SSI) was calculated according to Fischer and Maurer (1978) $SSI = (1 - Y_S/Y_N) / (1 - Y_{MS}/Y_{MN})$

Where Y_S is the yield under nitrogen stress (60 Kg. nitrogen)

Y_N is the yield under nitrogen non stressed (100 kg. nitrogen)

Y_{MS} is the yield means for all genotypes under 60 Kg nitrogen.

Y_{MN} is the yield means for all genotypes under 100 Kg nitrogen.

SSI values >1.0 indicate relatively stress susceptible and <1.0 indicate relatively stress tolerance.

Data for two years, two locations and two fertilizer rates were considered as eight environments designated EV-1 to EV-8). Test of homogeneity (Bartlett 1937) of the error mean squares across all environments was performed. Hence, the combined analysis was performed in this study according to Gomez and Gomez (1984). Least significant differences (LSD) were used for comparing means. Stability analysis for studied traits across all environments was performed according to Eberhart and Russell (1966). Three criteria would be realized to consider a genotype as stable one, these criteria as follows:

1-Regression coefficient significantly different from zero ($b \neq 0$) and not significantly different from unity ($b = 1$).

2- Non- significant sums of squares of the deviation of regression, i.e., $S^2d = 0$.

3- High performance with a reasonable range of environmental variation.

RESULTS AND DISCUSSION

1 -Analysis of variance

Data for separate trials were statistically analyzed as usual, test of homogeneity of the error mean squares across all environments was done. Error mean squares were not significant for all studied traits, indicating that errors were homogeneity, so the combined analysis was followed up in this investigation.

Table 2. Mean squares of combined analysis of variance for the studied traits.

Source of variation	df	Mean squares			
		Days to 50% flowering	Plant height	1000 grain weight	Grain yield per plant
Environments (Env)	7	618.32**	9303.11**	234.77**	5467.67**
Rep (Env)	16	1.99	44.98	0.55	6.37
Genotypes (G)	16	824.18**	21019.21**	47.70**	2894.2**
Env × G	112	10.47**	70.74**	2.82**	57.73**
error	256	1.50	42.26	0.40	5.95

*, ** significant at 0.05 and 0.01 levels of probability, respectively

The combined analysis of variance (Table 2) revealed highly significant differences among genotypes and environments for all the studied traits. Moreover, the genotype × environment interaction variance was also highly significant for all the studied traits, indicating that genotypes differently responded for environmental factors. In other words, the rank of a genotype differed among environments. The proportional participation of environment, genotypes and genotype by environment (G.E) interaction varied among traits. The participation of environments were 22.76, 15.73, 68.3 and 41.33% for days to 50% flowering, plant height, 1000 kernel weight and grain yield, respectively, revealing the important effects of environmental factors on grain yield and its components. The genotypes effects displayed the following ratios 69.4, 81.24, 27.0 and 49.97% for days to 50% flowering, plant height, 1000 kernel weight and grain yield, respectively, revealing the important role of genetic constitution on plant height and flowering date. Regarding the G.E, the participation ratios were 6.17, 2.0, 11.16 and 6.97 for days to 50% flowering, plant height, 1000 kernel weight and grain yield, respectively. It was apparent the trivial sharing of G.E interaction in most studied traits and especially on plant height. These results are in harmony with those found by Eweis (1998), Ali (2000), Ali *et al* (2006) and Mahmoud *et al* (2007) who found significant variances for genotypes, environments and the genotype x environment interaction for most the studied traits.

2 – Mean performance of genotypes

a- Days to 50 % flowering

Mean number of days to 50% flowering of the 16 grain sorghum genotypes for each environment and across 8 environments is presented in Table 3. The results showed different performance among environments. The mean of days to 50% flowering across all environments ranged from 64.3 for GD- 47815 to 80.3 days for RTX – 2817. The average of days to 50% flowering across all genotypes was 72.6 days.

Table 3. Means of days to 50% flowering, plant height, and 1000 grain weight for 16 grain sorghum genotypes across eight environments and over all genotypes.

Genotypes	2008				2009				Average
	Shandaweel		Sids		Shandaweel		Sids		
	100 kg N. EV_1	60 kg N. EV_2	100 kg N. EV_3	60 kg N. EV_4	100 kg N. EV_5	60 kg N. EV_6	100 kg N. EV_7	60 kg N. EV_8	
	Days to 50% flowering								
RTX – 430	71.3	76.0	73.0	78.7	69.0	74.0	72.0	77.0	73.9
RTX – 433	67.0	73.7	68.3	72.0	69.0	75.0	66.0	76.0	70.9
RTX – 436	70.3	74.3	72.0	80.0	68.3	73.0	71.0	76.0	73.1
RTX – 2817	76.7	82.7	78.7	86.0	76.3	80.3	79.0	83.0	80.3
RTX – 2862	73.0	81.3	75.0	82.3	76.0	83.3	73.7	85.0	78.7
ICSR – 273	78.7	83.7	79.0	82.7	73.7	78.0	78.3	83.0	79.6
ICSR – 138	76.3	82.3	76.0	83.0	73.0	79.0	75.0	80.3	78.1
ICSR – 89025	71.0	75.3	71.0	80.7	70.0	74.0	69.0	76.0	73.4
ICSR – 89037	69.7	74.7	73.7	78.7	73.0	79.0	75.3	82.0	75.8
R – 542	66.3	71.7	69.0	74.0	69.0	73.0	72.7	77.0	71.6
R – 625	64.3	68.7	66.0	72.0	64.0	69.0	61.0	64.0	66.1
R – 924	61.7	70.0	64.3	73.0	60.7	65.0	64.0	68.0	65.8
ZSV – 14	59.0	68.0	62.3	71.3	60.0	64.0	63.0	68.0	64.5
MR – 812	77.0	82.3	78.7	84.3	75.0	79.3	77.0	83.0	79.6
GD – 47809	63.0	68.7	65.0	72.0	61.0	65.0	65.0	68.7	66.0
GD – 47815	61.3	69.0	62.0	73.0	58.0	63.0	60.7	67.0	64.3
Average	69.2	75.1	70.9	77.7	68.5	73.4	70.2	75.9	72.6
Check variety	70.0	75.0	70.5	75.3	71.0	74.1	69.5	73.5	72.4
LSD at 0.05	2.4	2.1	2.0	2.2	1.7	1.7	2.1	2.4	2.1
	Plant height(cm)								
RTX - 430	130.0	91.7	121.7	91.7	123.3	103.3	116.7	95.0	109.2
RTX - 433	106.7	88.3	110.0	91.7	111.7	96.7	105.0	91.7	100.2
RTX - 436	118.3	98.3	111.7	100.0	121.7	101.7	116.7	101.7	108.8
RTX - 2817	103.3	90.0	101.7	88.3	110.0	100.0	115.0	98.3	100.8
RTX - 2862	115.0	93.3	115.0	91.7	111.7	95.0	108.3	95.0	103.1
ICSR - 273	215.0	176.7	200.0	165.0	213.3	183.3	201.7	185.0	192.5
ICSR - 138	203.3	166.7	191.7	163.3	196.7	170.0	186.7	160.0	179.8
ICSR - 89025	188.3	161.7	170.0	150.0	181.7	161.7	171.7	150.0	166.9
ICSR - 89037	188.3	148.3	168.3	138.3	180.0	158.3	173.3	148.3	162.9
R - 542	166.7	138.3	163.3	128,3	170.0	141.7	165.0	131.7	150.6
R - 625	168.3	141.7	155.0	128.3	175.0	140.0	160.0	130.0	149.8
R - 924	166.7	141.7	158.3	123.3	166.7	145.0	165.0	136.7	150.4
ZSV - 14	161.7	140.0	158.3	128.3	158.3	138.3	160.0	138.3	147.9
MR - 812	173.3	143.3	168.3	130.0	163.3	145.0	161.7	140.0	153.1
GD - 47809	141.7	106.7	126.7	98.3	126.7	111.7	121.7	111.7	118.1
GD - 47815	126.7	100.0	118.3	93.3	125.0	105.0	121.7	101.7	111.5
Average	154.6	126.7	146.1	119.4	152.2	131.0	146.9	125.9	137.9
Check variety	141.0	121.0	138.3	118.0	139.0	117.3	140.1	121.7	129.6
LSD at 0.05	11.0	9.6	10.1	8.5	12.0	11.3	10.7	10.1	10.5

Table 3. continued

Genotype	2008				2009				Average
	Shandaweel		Sids		Shandaweel		Sids		
	100 kg N. EV_1	60 kg N. EV_2	100 kg N. EV_3	60 kg N. EV_4	100 kg N. EV_5	60 kg N. EV_6	100 kg N. EV_7	60 kg N. EV_8	
	1000 grain weight (g)								
RTX - 430	26.9	22.0	25.3	20.5	25.1	21.6	24.1	20.0	23.2
RTX - 433	25.0	21.3	24.5	20.5	24.3	20.6	25.1	19.8	22.7
RTX - 436	24.5	20.6	24.4	20.9	24.3	19.9	25.3	22.3	22.8
RTX - 2817	24.4	21.3	26.3	23.5	24.9	21.5	25.6	22.0	23.7
RTX - 2862	26.7	23.0	26.4	22.5	26.4	23.1	26.2	22.5	24.6
ICSR - 273	25.5	23.1	26.5	23.3	26.8	24.6	26.6	23.5	25.0
ICSR - 138	26.5	24.3	27.2	24.9	27.9	25.4	25.8	24.3	25.8
ICSR - 89025	26.6	22.0	24.3	20.6	25.6	22.6	26.4	21.5	23.7
ICSR - 89037	26.5	23.4	26.1	21.7	27.4	24.0	26.4	22.0	24.7
R - 542	27.5	24.4	26.3	23.8	27.0	22.6	25.9	23.5	25.1
R - 625	27.7	25.3	26.1	22.0	27.3	21.5	26.1	20.3	24.5
R - 924	28.1	24.2	26.4	22.5	27.5	23.0	27.2	22.0	25.1
ZSV - 14	30.0	25.9	27.2	24.1	29.4	24.3	27.1	23.3	26.4
MR - 812	27.4	24.3	25.3	21.0	27.0	21.1	25.6	20.4	24.0
GD - 47809	27.3	24.1	26.1	23.0	26.9	22.3	26.7	22.2	24.8
GD - 47815	29.3	23.7	26.6	23.0	28.6	22.8	24.4	24.4	25.3
Average	26.9	23.3	25.9	22.4	26.7	22.6	25.9	22.1	24.5
Check variety	33.3	26.0	31.5	25.4	32.1	26.1	29.4	23.9	28.5
LSD at 0.05	1.3	1.3	1.5	1.2	0.9	1.0	1.2	1.0	1.2

Moreover, the results clearly showed that decrease nitrogen fertilizer from 100 Kg. /fad to 60 Kg /fad led to increased number of days to 50% flowering of genotypes at Shandaweel and Sids in the two seasons.

b- Plant height

Regarding plant height (Table 3), the results showed different performance of genotypes from year to year and from location to anther. Means plant height across all genotypes ranged from 119.4 cm at Sids under 60 kg nitrogen level in 2008 season to 154.6 cm at Shandaweel under 100 kg nitrogen fertilizer in 2008 season. This indicates that decrease of nitrogen fertilizer from 100 Kg /fad to 60 Kg /fad led to the decreased plant height of genotypes at Shandaweel and Sids in the two seasons.

Furthermore, the results showed that the average of plant height across all environments ranged from 100.2 cm for RTX-433 to 192.2 cm for ICSV-273.

c- 1000 grain weight

Regarding the 1000 grain weight, means of the 16 grain sorghum genotypes at each environment and across all environments were presented in Table 3. The results showed different response of genotypes from year to year and from location to another. The mean of 1000 grain weight across all genotypes ranged from 22.1 g at Sids under 60 kg nitrogen fertilizer in 2009 season to 26.9 g at Shandaweel under 100 kg nitrogen fertilizer in 2008 season, The average of 1000 grain weight across all environments ranged from 22.7 g for RTX-433 to 26.4 g for ZSV–14. Furthermore, the results clearly showed that decreasing nitrogen fertilizer from 100 Kg /fad to 60 Kg /fad led to the decreased 1000 grain weight of genotypes at Shandaweel and Sids in the two seasons. The check variety Dorado was significantly heavier grain yield compared with all genotypes over all environments.

d- Grain yield per plant:-

Means of grain yield per plant for sixteen genotypes across 8 environments and across all environments as well as nitrogen stress susceptible index are presented in Table (4).

The results showed different performances of grain yield per plant of 16 genotypes from year to year and from location to another. The mean grain yield per plant across all genotypes varied from 43.4 g at Sids under 60 kg nitrogen fertilizer in 2009 season to 66.4 g at Shandaweel under 100 kg nitrogen fertilizer in 2008 season, indicate that mean grain yield per plant of the 16 genotypes decreased clearly with decreasing nitrogen fertilizer from 100 Kg /fad to 60 Kg /fad at Shandaweel and Sids in the two seasons. Moreover, the results cleared that average of grain yield per plant for genotypes across all environments ranged from 39.9 g for RTX-433 to 77.4 g for ICSV–273. Six out of the sixteen genotypes significantly surpassed the general mean of grain yield per plant over all environments. 7 out of 16 genotypes showed highly significant superior grain yield compared with check variety Dorado across all environments.

Table 4. Means of grain yield for 16 grain sorghum genotypes across eight environments and stress susceptibility index (SSI).

Genotypes	Grain yield								Average	SSI
	2008				2009					
	Shandaweel		Sids		Shandaweel		Sids			
	100 kg N. EV_1	60 kg N. EV_2	100 kg N. EV_3	60 kg N. EV_4	100 kg N. EV_5	60 kg N. EV_6	100 kg N. EV_7	60 kg N. EV_8		
RTX - 430	50.8	36.0	48.5	32.8	47.6	36.7	46.3	31.3	41.3	1.01
RTX - 433	45.5	33.3	50.2	33.3	44.0	32.4	48.2	32.0	39.9	1.04
RTX - 436	62.2	42.5	57.3	39.6	57.7	44.1	55.9	39.5	49.9	1.00
RTX - 2817	57.7	41.5	53.2	41.1	53.3	43.1	50.7	40.5	47.6	0.78
RTX - 2862	56.3	41.7	46.8	31.8	62.6	44.6	56.6	37.1	47.2	1.04
ICSR - 273	85.6	69.8	83.3	66.3	89.6	72.3	85.3	67.2	77.4	0.67
ICSR - 138	83.1	68.7	72.5	61.4	81.1	69.5	75.3	62.9	71.8	0.55
ICSR - 89025	72.8	46.9	69.6	41.8	69.3	43.3	71.2	43.1	57.3	1.31
ICSR - 89037	80.3	62.8	77.3	56.9	83.1	57.6	77.8	56.3	69.0	0.97
R - 542	70.5	62.6	72.2	46.3	73.3	49.3	67.5	40.0	60.2	1.04
R - 625	60.1	43.2	70.5	43.0	64.6	43.7	69.3	33.7	53.5	1.31
R - 924	65.7	47.2	68.8	33.2	68.6	48.8	68.1	31.0	53.9	1.41
ZSV - 14	78.6	60.8	81.1	57.6	83.1	57.5	79.5	55.6	69.2	0.97
MR - 812	76.5	58.3	59.0	42.7	73.7	57.3	72.0	52.8	61.5	0.86
GD - 47809	55.0	42.5	53.9	40.3	50.0	36.9	54.5	37.1	46.3	0.91
GD - 47815	61.5	34.5	57.3	37.3	53.0	31.6	56.9	38.5	46.3	1.31
Average	66.4	49.5	63.8	44.1	65.9	48.0	64.6	43.4	55.7	-
Check variety	63.6	44.2	63.0	42.3	58.9	40.3	59.3	44.2	51.9	1.04
LSD	3.8	3.0	3.2	2.9	4.9	3.9	3.2	3.3	3.6	-

3- Stress Susceptible Index:

Nitrogen susceptibility Index (Table 4) for grain yield was estimated as the ratio of the deviation of performance at 60 kg /fad nitrogen fertilizer from the performance at 100 kg nitrogen fertilizer to that of the over all mean deviation in this particular population. The data showed that, the pest tolerant genotypes for low nitrogen fertilizer were RTX-2817, ICSV-273, ICSR-138, ICSR-89037, ZSV-14, MR-812 and GD-47809.

Results indicated different response of genotypes from year to year and from location to another for all the studied traits. Mean plant height, 1000 grain weight, and grain yield per plant of the 16 genotypes decreased clearly with decreasing nitrogen fertilizer from 100 Kg /fad to 60 Kg /fad at Shandaweel and Sids in the two seasons. It could be noticed that the best yielding ability lines were not always the most stable lines. In this context, the sorghum breeders keen to identify the best high yielding lines under nitrogen stress fertilizer and the best stable lines to combine each other to get hopeful stable and high yielding genotypes. It is of interest to indicate that the tolerant lines selected ICSV–273, ICSR–138, ICSR–89037, ZSV–14 and MR–812 showed the highest yielding ability across all environments. These results were in agreement with those obtained by Eweis (1998), Ali (2000), and Mahmoud *et al* (2007)

4- Estimated stability parameters

The joint regression analysis of variance for the studied traits is presented in Table (5). The variances among genotypes, environments and genotypes × environments interaction were highly significant for all the studied traits, indicating that genotype varied considerably across different environments. Furthermore, Env. + (Genotypes × environments) interaction was partitioned into environment (linear), genotype × environment interaction (linear) and sum of squares due to regression, b_i and pooled deviation mean squares, (S^2_d). Moreover, the G × E interactions were a linear function, which were significant or highly significant for all studied traits, except for days to 50% flowering. For that reason, the regression coefficient (b_i) and deviation from regression (S^2_d) pooled across the eight environments were calculated for each genotype. Significant genotype × environment mean squares for plant height, 1000 grain weight, and grain yield per plant indicate that genotypes genetically differed in their response to different environments when tested against pooled deviation. Furthermore, the highly significant pooled deviation for days to 50% flowering, 1000 grain weight, and grain yield per plant indicate that non linear component of genotype × environment interaction was operating. These findings were in agreement with those obtained by Eweis (1998), Ali (2000), Mourad *et al* (2000) Mostafa (2001), Ali (2006), Mahmoud *et al* (2007) and Mahdy *et al* (2011) At the same time, it was evident from Table 2 that the interaction of genotype × environment for all studied traits was highly significant. Such significant interactions encourage sorghum breeders to develop high yielding and more uniform genotypes under varied environmental conditions. High yield potential and average stability are due to most attributes involved in determining the wide adaptation of a new variety or hybrid (Eberhart and Russell, 1966).

Estimates of various stability parameters of the sixteen grain sorghum genotypes with respect to days to 50% flowering, plant height, 1000 grain weight, and grain yield per plant are presented in Tables (6 and 7). The stability parameters in these tables are: 1. the mean for different characters, 2. the regression coefficient (b_i) of the performance on environmental indices, and 3. deviation from regression (S^2_d). According to the definition of Eberhart and Russell (1966), a stable preferred variety would have approximately: 1. b_i = 1, 2. S^2_d = 0 and 3. a high mean performance. However, Johnson *et al* (1955), Paroda *et al* (1971) and Lin (1986) considered the squared deviation from regression as a measure of stability, while the regression was regarded as a measure of response of a particular variety to environmental indices.

Table 5. Stability analysis of variance for grain yield and other studied traits of 16 grain sorghum genotypes evaluated under eight different environmental conditions.

Source of variation	df	mean squares			
		days to 50% flowering	plant height	1000 grain weight	grain yield /plant
Genotypes	15	824.18**	21019.21**	47.70**	2894.2**
Env, Env. G	112	44.10**	622.98**	15.049**	375.76**
Env (linear)	1	3917.29**	61943.68**	1424.79**	35880.6**
G. Env (linear)	15	7.99	236.15**	4.211*	162.00**
Pooled Deviation	96	9.39**	44.67	2.057**	39.32**
pooled error	240	1.53	42.26	0.40	5.95

*, ** significant and highly significant at 0.05 and 0.01 levels of probability, respectively

For days to 50% flowering Table (6), stability parameters indicated that the genotypes varied in their b_i values as well as S^2d. It could be noticed that the regression coefficient (bi) for genotypes No. 1, 3,4,13 and 14 were insignificant from unity and the deviation from regression (S^2d) were insignificant from zero, indicating that these genotypes could be considered stable for days to 50% flowering. The other genotypes were unstable (S^2d was significant from zero).

Table 6. Stability parameters of days to 50 % flowering and plant height of 16 grain sorghum genotypes evaluated under eight different environmental conditions

Genotype	Days to 50% flowering			Plant height		
	mean	$b_i \pm$ S.E	S^2d	mean	$b_i \pm$ S.E	S^2d
1	73.9	0.92 ± 0.07	-0.4	109.17	1.12 ± 0.09	-10.33
2	70.9	0.86 ± 0.29	18.7**	100.21	0.63 ± 0.10	-2.88
3	73.1	1.03 ± 0.12	1.8	108.75	0.66 ± 0.08	-15.84
4	80.3	0.97 ± 0.07	-0.5	100.83	0.54 ± 0.16	56.40*
5	78.7	1.21 ± 0.29	18.5**	103.13	0.73 ± 0.09	-13.94
6	79.6	0.83 ± 0.21	9.3**	192.50	1.28 ± 0.11	7.79
7	78.1	1.01 ± 0.13	2.5*	179.79	1.20 ± 0.11	6.23
8	73.4	1.08 ± 0.15	3.7**	166.88	0.97 ± 0.13	23.32
9	75.8	0.88 ± 0.30	20.8**	162.92	1.26 ± 0.09	-10.22
10	71.6	0.76 ± 0.26	14.5**	150.63	1.25 ± 0.09	-11.69
11	66.1	0.73 ± 0.30	20.5**	149.79	1.24 ± 0.14	32.21
12	65.8	1.18 ±0.14	3.3**	150.42	1.16 ± 0.11	0.69
13	64.5	1.22 ± 0.12	1.8	147.92	0.93 ± 0.09	-13.54
14	79.6	0.95 ± 0.07	-0.3	153.13	1.11 ± 0.11	1.47
15	66.0	0.99 ± 0.12	2.2*	118.13	0.96 ± 0.13	27.38
16	64.3	1.39 ± 0.18	6.6**	111.46	0.95 ± 0.03	-38.51
17	72.35	0.65±0.12	1.65	129.53	0.78 ± 0.09	-5.67
mean	72.6	-	-	137.85	-	-
LSD0.05	2.1	-	-	10.5	-	-

Regarding plant height, the stability parameters indicated that the genotypes varied in their bi values as well as S^2d. It could be noticed that the regression coefficient (b_i) for genotypes No. 1,7,8,11,12,13,14,15 and 16 were insignificant from unity and the deviation from regression(S^2d) were insignificant from zero, indicating that these genotypes could be considered as stable for plant height. The other genotypes were unstable (b_i was significant from unity).

For 1000 grain weight (Table 7), the stability parameters indicated that the genotypes varied in their bi values as well as S^2d. It could be noticed that the regression coefficient (b_i) for genotypes No. 2,5,10 and 15 were insignificant from unity and the deviation from regression (S^2d) were insignificant from zero, indicating that these genotypes are considered stable for plant height. The other genotypes were unstable (b_i was significant from unity and / or S^2d was significant from zero).

The stability parameters (b_i and S^2d) for grain yield per plant are presented in Table (7), results revealed that the genotypes varied in their bi values as well as S^2d. It could be noticed that the regression coefficient (b_i) for genotypes No. 3 (RTX-436), 6 (ICSV-273) and 9 (ICSR-89037) didn't significantly differ from unity and the deviation from regression (S^2d) didn't significantly differ from zero, indicating that these genotypes could be considered as stable for grain yield per plant. Two genotypes had grain yield higher than the grand mean (ICSV-273 and ICSR-89037). These results are in line with those reported by El-Morshedy *et al* (2000), Mostafa (2001), Mahmoud *et al* (2007) and Mahdy *et al* (2011).

Table 7. Stability parameters of 1000 grain weight and grain yield per plant of 16 grain sorghum genotypes evaluated under eight different environmental conditions

Genotype	1000 grain weight			Grain yield per plant		
	mean	$b_i \pm$ S.E	S^2d	mean	$b_i \pm$ S.E	S^2d
1	23.2	1.18 ± 0.11	0.74*	41.3	0.75 ± 0.05	0.4
2	22.7	1.08 ± 0.08	0.20	39.9	0.71 ± 0.11	19.7**
3	22.8	0.90 ± 0.20	3.05**	49.9	0.89 ± 0.06	3.9
4	23.7	0.75 ± 0.22	4.06**	47.6	0.64 ± 0.07	7.2*
5	24.6	0.95 ± 0.04	-0.22	47.2	0.93 ± 0.18	66.7**
6	25.0	0.67 ± 0.14	1.43**	77.4	0.90 ± 0.07	5.6
7	25.8	0.54 ± 0.13	1.14**	71.8	0.70 ± 0.12	29.5**
8	23.7	1.07 ± 0.15	1.69**	69.2	1.17 ± 0.08	11.0**
9	24.7	1.02 ± 0.12	0.92*	69.0	1.12 ± 0.07	4.7
10	25.1	0.83 ± 0.08	0.18	60.2	1.19 ±0.18	74.0**
11	24.5	1.29 ± 0.20	3.03**	53.5	1.30 ± 0.19	75.0**
12	25.1	1.20 ± 0.05	-0.20	53.9	1.51 ± 0.15	48.9**
13	26.4	1.14 ± 0.13	1.18**	57.3	1.39 ±0.08	9.8**
14	24.0	1.31 ± 0.15	1.52**	61.5	0.99 ± 0.22	106.0**
15	24.8	1.03 ± 0.06	-0.08	46.3	0.73 ± 0.10	15.8**
16	25.3	1.05 ± 0.25	5.32**	46.3	1.08 ± 0.18	67.9**
17	28.5	1.62 ± 0.14	2.90**	51.9	0.95 ± 0.11	21.7**
mean	24.5	-	-	55.8	-	-
$LSD_{0.05}$	1.2	-	-	3.6	-	-

b_i = Regression coefficient.

S^2d = deviation from regression.

*, ** significant at 0.05 and 0.01 probability levels, respectively.

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تقييم الأداء و الثبات لبعض التراكيب الوراثية من الذرة الرفيعة للحبوب

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أجريت هذه التجربة خلال الموسم الصيفى لعامى ٢٠٠٨ و ٢٠٠٩ حيث قيم عدد ١٦ تركيب وراثي مختلفة المنشأ من الذرة الرفيعة للحبوب تحت معدلين من التسميد النيتروجينى (٦٠ & ١٠٠ كجم نيتروجين/ فدان) وذلك فى محطة البحوث الزراعية بكلاً من شندويل وسدس (٨ بيئات).

أظهر ت النتائج وجود اختلافات عالية المعنوية بين التراكيب الوراثية و بين البيئات وذلك بالنسبة لجميع الصفات محل الدراسة. كما كان تفاعل التباين بين التراكيب الوراثية والبيئات عالى المعنوية لجميع الصفات المدروسة. علاوة على هذا فقد اوضحت النتائج ان التراكيب الوراثية قد اظهرت تباين فى سلوكها من سنة لإخرى ومن موقع لموقع اخر لجميع الصفات. علاوة على ذلك أظهر ت النتائج أن متوسط ارتفاع النباتات ووزن الالف حبة ومحصول الحبوب للنبات بالنسبة الى الستة عشر تركيب وراثى انخفض بوضوح نتيجة انخفاض معدل التسميد النيتروجينى من ١٠٠ كجم ازوت للفدان الى ٦٠ كجم ازوت للفدان وذلك بكلا من شندويل و سدس.

اظهر تحليل الانحدار المشترك للتباين للصفات التى تم دراستها وجود اختلافات عالية المعنوية بين التراكيب الوراثية وبين البيئات والتفاعل بين التراكيب الوراثية و البيئات لكل الصفات المدروسة وهذا يشيرإلى أن التركيب الوراثي يختلف اختلافا كبيرا عبر البيئات المختلفة. وعلاوة على ذلك، فان التفاعل بين التراكيب الوراثية و البيئات (دالة خطية) كان معنويا او عالى المعنوية لجميع الصفات المدروسة فيما عدا عدد الايام من الزراعة حتى ٥٠% تزهير.

اظهرت قيم الثبات (bi و S2d) بالنسبة لصفة محصول الحبوب للنبات ان التراكيب الوراثية تختلف فى قيمتها من حيث bi وكذلك تختلف فى قيمتها من حيث S2d. ويمكن ملاحظة ان معامل الانحدار bi للتراكيب الوراثية (RTX-436, ICSV-273 و ICSR-89037) كان غير معنويا عن الواحد كما كانت قيمة الانحراف عن الانحدار S2d غير معنوية عن الصفر وهذا يشير الى ان هذه التراكيب تعتبر ثابتة بالنسبة لصفة المحصول وقد احرزت اثنين من هذه السلالات (ICSV-273 و ICSR-89037) محصول حبوب اعلى من المتوسط العام للسلالات وبالتالي تعتبر تراكيب مثالية.